WHAT IS THE LEGITIMATE USE OF WATER?[1]

By Caleb Mills Saville[2]

In its broad and general sense the question, "What is the legitimate use of water?" opens up such a large opportunity for discussion that it seems impracticable at this time to attempt to do more than consider a few special problems.

For example, is it a legitimate purpose to use pure water brought at great expense from long distances for the extinguishment of fires, or is it in keeping with modern thought in conservation to draw from the city supply large quantities of filtered water for use in mechanic arts when other water will suffice? Related to this phase is the moot question as to the propriety and desirability of selling water to a large consumer at or below cost in order to obtain his trade. These, perhaps, may be called questions of ethics, but every gallon of water so used hastens the time when an additional supply is needed, and with every increase in supply progressively greater difficulty in obtaining proper water for domestic use must be encountered. This results from the growing scarcity of good water supply grounds in the vicinity of our cities and the mounting cost of construction works for extension and for water purification.

Among the many phases of this problem is the quantity of water to be judged as legitimately used or useful for that purpose which must in the end take priority over all others; namely, the use of water for human needs and for potable purposes.

A statement of this portion of the problem resolves itself most naturally into a presentation of statistics and results of inquiry. This in turn can only be discussed in a very general way without study of data, some of which it is the author's purpose to present in the hope that deductions may be drawn or ideas suggested which may be of value for the improvement of water works operation.

[1] Presented at the Montreal Convention, June 23, 1920. Discussion is invited and should be sent to the Editor.

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The primary object is to serve the people with a necessary commodity in as economical and efficient a manner as possible.

In studying the data collected and the conditions under which they were obtained, it is evident that *rate* of use is nearly as important as the actual consumption of water; that these two are interrelated, and that present day living conditions and requirements must be considered.

There are causes for increase in consumption other than waste, and a bare comparison of per capita consumption figures may be most misleading.

The basis on which the number of consumers is estimated, the character of the houses, the requirements of the inhabitants in installation of modern plumbing facilities, the extension of sewers and other growing demands for modern personal conveniences, have much to do with the legitimate use of water. The pressure under which water is supplied, the increase in pressure in the same system due to additions and reconstruction, and the requirements for mechanic arts and commercial purposes are of no small effect. All of them must be given weight when comparisons are made of unit consumption records.

As recently as 15 years ago many tenement houses in our largest cities were unsupplied with plumbing fixtures other than a cold water faucet and a community water-flushed toilet. Today few apartment blocks of even low rent value in our cities are not fully equipped with individual conveniences which promote a comparatively lavish use of water, and public health authorities are actively pushing these requirements.

These tendencies of the times must be recognized by the water works man and provision made for future water service in all communities to meet the present demands of city dwellers.

This probably means a greatly increased per capita domestic demand during a transition period of a score of years perhaps in suburban and country localities and thereafter in all localities a more slowly advancing rate of increase which would tend to approach a uniform rate of consumption.

For this transitition period it seems probable that the rate of increase per capita per year may be at least from 2 to 3 gallons more than the present normal and thereafter provision should be provided for an annual increase of from $\frac{1}{2}$ to $\frac{3}{4}$ gallon per day per consumer.

The first and most practical method for successfully coping with this legitimate increase in the use of water is, of course, the elimination of needless and useless waste. Methods for accomplishing this result, admirable in itself, however, should be carefully considered with reference to cost and the results practicable of accomplishment in individual cases. While it is always commendable to stop waste of any kind, the immediate financial results of saving the last drop of water are not so apparent in connection with an unfiltered gravity supply from an abundant source as they are when all the water must be pumped or filtered, or both.

The city of Hartford, Conn., is practically fully metered, the only unmetered supplies being fire protection services unused except in emergencies and some use of water for street watering, sewer flushing, water main flushing and by fire hydrants. In 1915 a rather intensive study was made of water use conditions with the following results:

	MILLION GALLONS PER DAY	GALLONS PER CAPITA	PER CENT OF TOTAL
Domestic	4.74	33	50.4
Manufacturing	2.73	19	29.0
Public	0.43	3	4.6
Unaccounted for	1.50	10.5	16.0
Totals	9.40	65.5	100.0

In 1919 the average daily draft has increased to 11,880,000 gallons per day, and while as yet no close study has been made, it seems likely that although the unaccounted-for water may have somewhat increased, it is still less than 15 gallons per capita per day or perhaps 20 per cent of the total consumption of the city.

Manufacturing and industrial. The amount of water used from the public supply for manufacturing and industrial purposes in Hartford is quite inconsiderable considering the numerous and extensive plants which are located here. This condition is accounted for by the fact that much of the water used for these purposes is furnished by private supply from driven wells or nearby streams. This condition, too, somewhat accounts for Hartford's comparatively low consumption and undoubtedly, if as much water were drawn here from the public supply as in some other cities with similar industrial activity, the rate of per capita consumption would be considerably increased from perfectly legitimate uses.

Public. A study of the principal uses of water for public purposes indicates that the amount of water so used probably does not exceed 450,000 or 500,000 gallons per day, allocated about as given below:

SERVICE	MILLION GALLONS PER YEAR	GALLONS PER CAPITA PER DAY
Fire—Station use	3.7	0.070
Extinguishing fires	3.3	0.063
Parks	11.7	0.223
Police station use	0.9	0.017
Streets—Drinking fountains	0.4	0.007
Horse fountains	2.3	0.042
Sprinkling and flushing	34.1	0.648
Miscellaneous	0.4	0.007
Schools	24.7	0.473
Miscellaneous buildings	20.8	0.397
Estimated unaccounted for	55.2	1.053
Totals	157.5	3.000

The total use of water for extinguishing fires is comparatively small in the course of a year. The rate of demand, however, for short periods is often very great, so great, in fact, that in cities of 100,000 to 150,000 population a reasonable requirement for fire protection service often equals or exceeds the maximum hourly rate of draft of an ordinary day. The total amount of water used by the Fire Department of Hartford in the past year was about 7,000,000 gallons, or a little over a pint per capita per day, of which about one-half was used in the maintenance of 16 stations, including washing of hose and apparatus. The remainder was used in extinguishing fires.

The following data from Fire Department records of 1914 is an indication of service conditions in this city:

Total actual fire alarms	628
Number fire calls at which water was used	105
Number of times pump service available	63
Number of hose streams in use, average	2
Length of hose line, average, feet	380
Usual size nozzle, inches diameter	1 to 1¼
Average hydrant pressure in service, pounds	60 to 80
Average pump pressure, pounds	100 to 200
Total amount of water used, gallons	3,000,000

Value of property included in the fires	$7,973,109
Insurance thereon	3,348,310
Insurance loss	14,590

The following table shows the duration of hose service at fires in 1914:

NUMBER OF FIRES	DURATION OF SERVICE
50	15 minutes
25	15 minutes to 30 minutes
15	30 minutes to 1 hour
11	1 hour to 2½ hours
2	2½ hours to 4 hours
2	4 hours to 6 hours

Of the 105 alarms at which water was used, three or more streams were in service at only 16. There were seven calls at which five or more streams were used, four at which nine or more were used, and one at which thirteen streams were in service.

An analysis of the seven calls at which five or more streams were in service is given in table 1.

TABLE 1

Analysis of the seven calls where five or more streams were in service

DATE 1914	NUMBER STREAMS		LENGTH OF TIME IN SERVICE			DISCHARGE OF STREAM GALLONS PER MINUTE			MAXIMUM RATE OF DISCHARGE			EQUIVALENT NUMBER 250 GALLONS PER MINUTE STREAMS	ESTIMATED TOTAL AMOUNT USED, GALLONS
	2½ in.	3 in.	Aver. h. m.	Min. h. m.	Max. h. m.	Aver.	Min.	Max.	h. m.	g. p. m.	m. g. m.		
Jan. 20	9	—	4 20	3 —	6 —	260	240	285	3 —	2,360	5.40	9.5	613,370
Feb. 21	11	2	2 35	2 —	4 30	365	175	645	2 —	4,765	6.86	19.1	648,380
Feb. 26	8	2	2 20	1 —	4 15	315	260	425	1 —	3,130	4.50	12.5	426,530
May 23	5	—	— 30	— 10	1 25	225	200	270	— 10	1,120	1.61	4.5	35,770
Dec. 4	3	2	1 25	— 35	4 —	335	260	450	— 35	1,665	2.40	6.7	151,220
Dec. 4	7	2	1 25	— 35	2 10	325	245	565	— 35	2,930	4.22	11.7	239,670
Dec. 18	5	—	— 55	— 15	1 30	270	210	300	— 15	1,340	1.93	9.3	67,250

These seven fires used a total of 2,182,190 gallons, or about two-thirds of the entire amount used to put out fires, leaving 1,117,810 gallons to be used by the other 98 calls, or an average of about 11,400 gallons per fire call.

On January 29–30, 1917, occurred the most serious fire that has yet visited Hartford. On that date a large department store was destroyed with loss aggregating $613,000. Twenty pieces of apparatus were in action, including 13 pumping engines and a water-tower. In all the equivalent of 38 single streams were employed simultaneously at this fire. It is estimated that about 3,500,000 gallons of water were used at this time, and for four consecutive hours the draft was at a rate of 10,000 gallons per minute. This rate, it is interesting to note, is exactly that recommended for Hartford's Congested District by the engineers of the National Board of Fire Underwriters in 1916.

Unaccounted for water. This amount of water is the difference between the amount registered on the master meter on the supply pipe line and the sum of consumer meters, plus a comparatively small amount to known unmetered uses.

The quantity thus drawn is due to leakage from underground main pipes and services, under-registration of meters, probably some illegitimate use and some unmetered public use, as for flushing water mains, factory tests of private fire protection systems, etc.

The total amount unaccounted for is estimated as less than 15 gallons per capita per day. In his report on the Boston Metropolitan Water District, the late Dexter Brackett, one of the foremost water distribution engineers of the country, stated this amount to be "a minimum quantity and could only be maintained by a thorough meter system and constant inspection." John R. Freeman, in his report on New York's Water Supply (1900), puts 10 gallons per inhabitant per day as "the irreducible waste with every service pipe metered and most rigid inspection."

Domestic consumption. What may be the proper and legitimate amount of water for domestic purposes is a complex problem that includes many factors not capable of exact solution, because of their dependence on human habits and social requirements as well as necessities of life.

The accompanying tables give data concerning conditions in several municipalities where accurate and carefully obtained information has been available.

As showing the tendency for increase in the per capita consumption, data from the Boston (Mass.) Metropolitan District is available and comparison of five-year periods are given in table 2. These municipalities are similar in their characteristics and are practically

residential communities; that is to say, they have no large industries which dominate the locality and a very large proportion of the population of all of them have their employment in Boston. These cities have all been fully metered for the past ten years or more. During the past five years the consumptions given in table 2 have been observed.

TABLE 2

Water consumption in residential cities in Eastern Massachusetts, with a complete metered service

MUNICIPALITY	YEAR 1914		YEAR 1918		PER CAPITA CONSUMPTION		INCREASE IN PER CAPITA CONSUMPTION PER YEAR
	Population	Consumption mil. gals.	Population	Consumption mil. gals.	1914	1918	
Malden	48,950	2.237	52,150	3.255	46	62	3.2
Medford	26,430	1.259	34,600	2.161	48	62	2.8
Melrose	16,920	0.933	17,870	1.181	55	66	2.2
Milton	8,630	0.347	9,250	0.435	40	47	1.4
Swampscott	6,770	0.440	7,960	0.606	65	76	2.20
Means and totals...	107,700	5.216	121,830	7.638	51.8	62.7	2.18

Increase in population 13 per cent.
Increase in consumption 21 per cent.

In their report (1915) on additional water supply for the city of Providence, R. I., F. P. Stearns and others state (page 6):

> The city of Providence has for many years sold water on a meter basis, and the consumption per capita is low. It is, however, higher at the present time than it was ten or twelve years ago, the increase in per capita consumption being on an average about three-quarters gallon per capita per day.

In a report on the "Enlargement and Improvement of the Baltimore (Md.) Water Supply," J. R. Freeman and F. P. Stearns state (page 24) it must be recognized "that there is a strong tendency manifest in nearly all the large American cities for the per capita supply of water to increase from year to year."

In his report on "Water Supply for the City of Cambridge, Mass." (1903, page 18), Freeman C. Coffin said:

"The rate of increase in the consumption of water of 5.475 per cent per year or about 30 per cent in five years is higher than that of the increase in population which is 13 per cent in five years. This is explained by the increase in the rate of the per capita consumption or the daily consumption of water by each person; that is, the consumption of water not only increases on account of the increase in population but as the population increases the use of water per person increases," and (page 13): "While the increase in consumption was from 1,626,000 to 8,028,914 (gallons daily) in 30 years or about 5.5 per cent per year the increase in population is from 45,166 in 1872 to 94,152 in 1903 or about 2½ per cent per year or about one-half the rate of the increase in the consumption."

It has been said that there is no basis for establishing a rational system of flat charges, and that such a scale of rates is at best a makeshift, with one man's guess as good as another's. This is, without doubt, an absolutely correct statement, yet a close analysis of the use to which water is put in a small residential community enables some comparisons to be made of the use of water for domestic purposes and of the cost of water to consumers by metered and flat rates. One must, however, bear in mind the fact that such a comparison is not an entirely true index of the amount of water which would be drawn by these same houses were they paying for service under the flat rate system uncontrolled by the meter in the cellar.

In a section which may be profitably under consideration there were 1,878 persons served by 379 connections with the water main system, all of which are metered. The average family was, therefore, 4.9 people, using an average of 25.2 gallons per capita. The district owns and maintains its pipe system but purchases water from the Hartford Water Department, which supplies, maintains and reads house meters and makes collections. By meter rates at 12 cents per 100 cubic feet and a minimum charge of $5.00 per connection, the district paid $3,414.55 for water last year at an average rate of about $9.00 per connection.

Eight years ago the district installed its system of about 5 miles of pipe, mostly of 4-inch, 6-inch and 8-inch sizes, at a cost of about $26,000. An average of fixture rate charges paid to 27 private water companies in Connecticut similar in character to the district under consideration, gives the following rate schedule in force prior to 1918:

	per year
Single family (or faucet)	$6.00
Water closet, one	4.00
Bath tub, one	4.00
Set tubs, two tubs	1.50
Sill cock or use of hose	5.00
Total	$20.50
Extra:	
Additional closet	$1.50
Additional bath tub	2.00
Horse or cow	4.00

By metered rates in use prior to 1918–19 by private water companies in Connecticut, the price charged per 1,000 gallons ranged from 25 cents to 40 cents, with a majority of the companies charging 30 cents.

The amount of water required and its comparative cost at a fixture charge of $20.50 per year and at a metered rate of 30 cents per 1,000 gallons are given in table 3.

TABLE 3

Comparison of fixture and meter rates

RATE GALLONS PER CAPITA PER DAY	TOTAL GALLONS PER DAY	TOTAL GALLONS PER YEAR	AT FIXTURE RATE OF $20.50 PER YEAR	AT METER RATES OF 30 CENTS PER 1,000 GALLONS
			*cents**	*dollars*†
20	100	36,500	56.2	10.95
25	125	45,600	45.0	13.68
30	150	54,800	37.4	16.44
40	200	73,000	28.1	21.90
50	250	91,700	22.6	27.50

* Cents per 1000 gallons.

† Dollars per year.

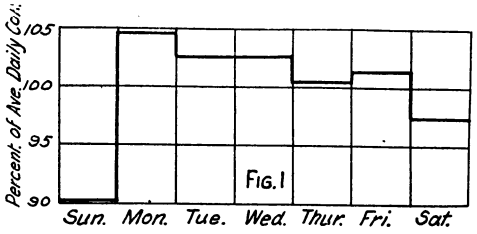
In the district studied, of 48 premises with single faucet only and accommodating 300 people, the average daily consumption was at a rate of 8.8 gallons per day per capita. Of these, 29 premises had a consumption below the average and 19 above that figure. Of the 29 below, 14 had a consumption of 6 gallons per day or less per person and of the 19 above, nine had a consumption of 12.0 or over.

These figures explain in some degree the low rates of water use given for European cities. It appears that without modern con-

veniences, such as bath tubs, water-flushed toilets and set tubs with running water, the average consumption of water per person per day is about 9 gallons.

In full-plumbed houses in this district, and by that is meant those having the conveniences mentioned above, 75 premises accommodating 312 people, used an average of 28.4 gallons per day.

From the above analysis it appears that the cost of metered water ordinarily is cheaper to the consumer than by fixture rates and he is



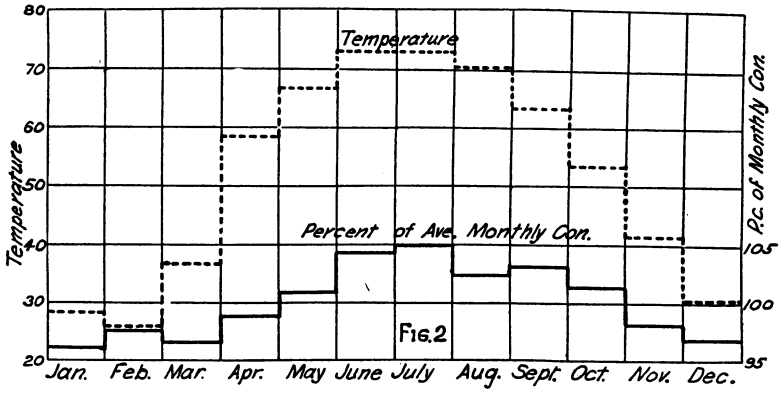


Fig. 1. Comparison of Actual and Average Daily Consumption

Fig. 2. Comparison of Actual and Average Monthly Consumption

thus led to more lavish use. On the other hand the general installation of meters tends to cut down waste of water. The net result of this combination may be that while legitimate household use of water seems to be increasing, the amount pumped or drawn from storage reservoirs is only slowly affected.

The relative consumption of water by months, days and hours is given in figures 1, 2 and 3.

Table 4 shows the use of water in dwellings of various character and conditions of plumbing. That the use of water is concurrent

with these peculiarities is plainly evident by a comparison of the relative amounts of water used in the several houses with the number and kind of plumbing fixtures. Besides the use of water by plumbing facilities the extensive use of automobiles also is a factor which should not be overlooked as it involves the continual washing oftentimes of several machines.

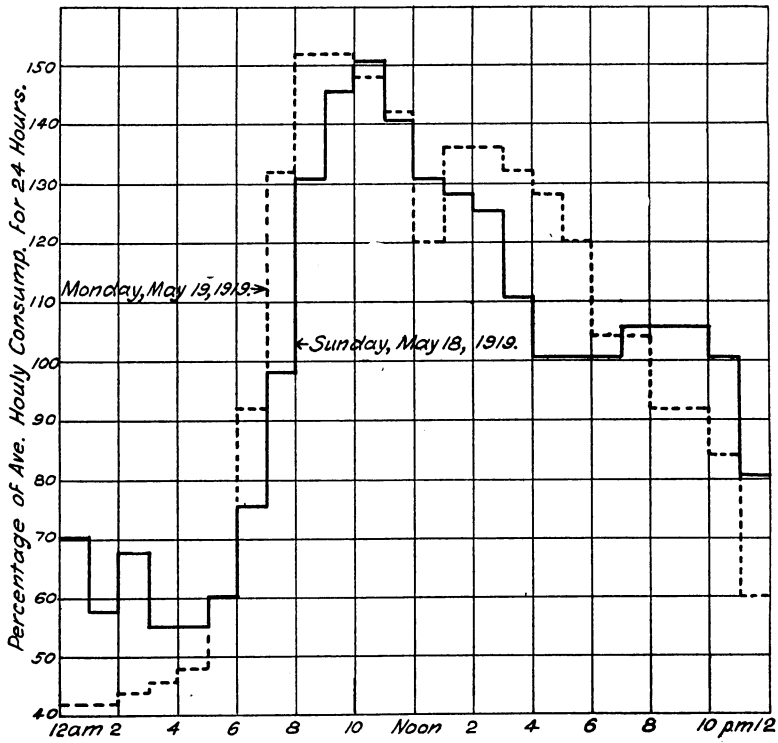


FIG. 3. COMPARISON OF ACTUAL AND AVERAGE HOURLY CONSUMPTION FOR 24-HOUR PERIOD

Note: Average Sunday consumption 8 a.m. to 4 p.m. was 132.9 per cent of the Sunday average. Average Monday consumption 7 a.m. to 6 p.m. was 136.2 per cent of the Monday average.

Table 5 gives a summary of the use of water in 661 premises of various kinds housing 5,937 persons and is believed to be representative of average conditions in Hartford. As all of these premises are metered and have been for a number of years it is reasonable to presume that the use of water in them has become stable.

TABLE 4

Per capita water consumption in houses in Hartford

LOCATION	ASSESSED VALUATION	TANK CLOSETS	FLUSH CLOSETS	WASH BASINS	BATH TUBS	SET TUBS	SHOWER BATHS	NO. OF PERSONS	WATER USED IN 6 MONTHS	GALLONS PER CAPITA PER DAY
Single houses										
1	$45,000	10	None	9	7	3	7	9	28,950	133
2		4	None	4	4	3	None	4	8,600	88½
3	33,000	7	None	8	6	3	?	6	11,800	82
4	3,000	None	2	2	1	2	None	4	7,800	81
5	3,500	2	None	2	1	2	1	2	3,900	81
6	8,000	1	1	3	2	3	1	4	7,200	75
7	25,000	None	7	7	4	3	2	6	9,600	66
8		None	5	4	3	3	1	11	17,000	64
9	1,700	1	None	1	1	2	None	4	6,000	62
10	1,500	1	None	1	1	2	None	4	5,800	60
11	13,000	3	None	3	3	2	None	5	6,980	58
12		1	None	1	1	2	None	2	2,650	54½
13		None	3	3	3	2	1	6	6,300	44
14	2,800	1	1	2	2	2	None	7	5,000	30
15	1,500	1	None	1	1	2	None	4	2,500	26
16	6,000	2	None	1	1	2	None	3	1,800	25
Two-flat houses										
17	4,000	2	None	2	2	2	None	8	8,400	44
18	16,000	4	None	4	3	3	None	4	4,550	43½
19	6,200	1	3	3	2	4	None	7	7,300	43
20	4,200	2	None	2	2	2	None	10	9,800	41
21	7,000	4	None	4	2	4	None	12	10,850	37½
22	8,500	3	None	3	3	4	None	8	7,050	36½
23	6,200	3	None	3	3	2	None	7	5,600	33
24	7,000	3	None	3	2	2	1	10	7,000	29
25	3,000	2	None	2	2	2	None	8	5,249	28
26	4,300	2	None	None	None	1	None	11	7,500	28
27	4,600	2	None	2	2	1	None	7	4,600	27
18	4,500	2	None	2	2	3	None	8	4,850	25
29	5,500	1	2	3	3	2	None	6	3,500	24
30	4,500	2	None	2	2	2	None	15	6,000	17
Three or more flat houses										
31	5,500	6	None	None	None	None	None	31	32,400	43
32	12,000	6	None	1	6	6	None	27	25,600	39
33	89,500	1	17	15	17	6	None	50	40,600	33½
34	5,600	3	None	3	3	6	None	10	6,300	26
35	4,500	3	None	3	3	6	None	17	8,800	21½
36	9,000	6	None	6	6	12	None	25	12,750	21
37	10,000	6	None	6	6	6	None	23	10,100	18
38	4,500	3	None	3	3	6	None	17	6,600	16
39	4,800	6	None	6	6	None	None	19	5,300	12
40	15,500	3	None	3	3	3	None	19	5,280	11

For mixed domestic use 35 gallons per capita seems ample at the present time. For estimate of 10 years hence, 40 gallons per capita per day seems none too small.

The relative character of the houses can be readily observed in the amount of water used per person for domestic purposes. This

TABLE 5

Average conditions of domestic consumption

	SERVICES	PERSONS	CUBIC FEET PER YEAR	PER SERVICE		PER CAPITA
				Persons	Gallons per day	Gallons per day
Apartment houses.....	9	462	1,394,300	51.4	318	62.0
6 tenement houses.....	76	1,602	1,987,000	21.0	536	25.5
3 tenement houses.....	66	828	1,145,400	12.5	355	28.4
2 tenement houses.....	208	1,543	2,268,100	7.4	223	30.0
Single houses, 3.....	128	570	866,700	4.5	139	31.2
Single houses, 2.....	138	743	1,630,100	5.4	242	45.7
Single houses, 1.....	36	189	748,900	5.3	427	81.4
	661	5,937	10,040,500	9.0	312	34.4

does not mean entirely for personal consumption, as in the case of the single-faucet houses previously noted, but it reflects the more lavish use of water for bathing, automobile washing, lawn sprinkling, etc.

Single dwellings average from 9 to 109 gallons per capita, with ordinary use, as stated above, at a rate of about 35 gallons per capita per day.